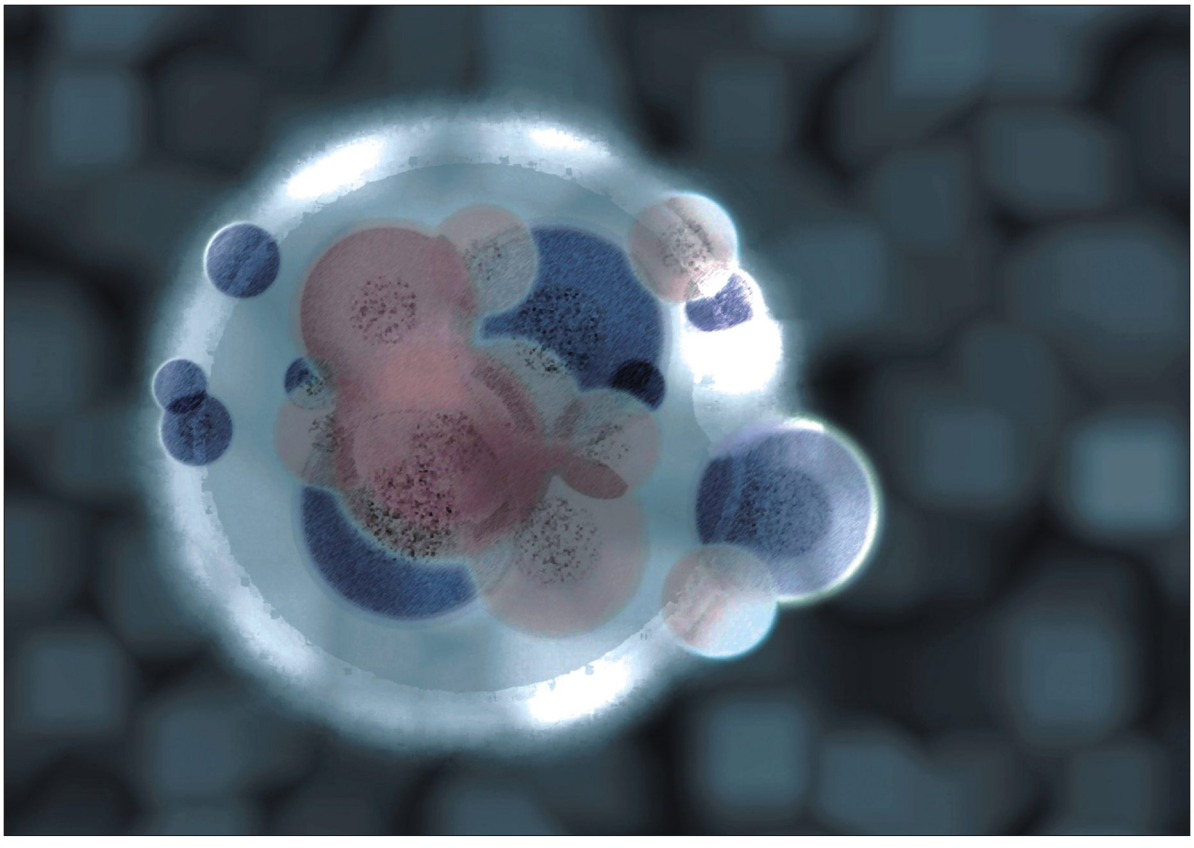

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Research Article
Physicochemical Study on Lactose-Free Biscuits and Brownness Cakes

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Abstract

Background and Objective: Nowadays lactose-free/reduced products are in demand to alleviate symptoms of lactose intolerance in suffering individuals where most humans had deficiency of lactase intestinal enzyme. The goals of the study were to produce lactose free products as brownness cakes and biscuits. **Materials and Methods:** This study was performed by preparing two free lactose formulas products. The obtained products were evaluated their qualities using the methods of chemical composition, baking quality, color parameters, texture properties, freshness and sensory evaluation. Data represented as a mean of triplicate samples ±Standard Deviation and evaluated using the analysis of variance and differences between means of parameters (ANOVA, one way). **Results:** Physicochemical studies showed that lactose free biscuit characterized with its higher contents of protein (13.49%) and fiber (041%) and lower fat (22.75%) compared to control sample. Also, lactose free brownness cake contained higher protein (7.55%) and lower moisture (7.29%) and fiber (0.98%) compared to control sample. Hunter color parameter showed that lactose-free biscuits and brownness cake were slightly darker than control sample. Sensory evaluation indicated that lactose-free biscuit was affected slightly on taste and color. Also, lactose free brownness cakes was rated slightly higher in their odor (19.23) than control sample (17.80). Furthermore, lactose-free brownness cakes not affected significantly in color, taste, texture, appearance and overall acceptability. Texture profile analysis of lactose-free biscuit characterized with lower fracturability (23.08 N), adhesiveness (0.00 mJ), adhesiveness force (0.03 N) and chewiness (1.10 mJ) compared to biscuit of control sample. Also, Lactose free Brownness cake characterized with its lower hardness (9.10 N), adhesiveness force (0.07 N), springiness index (0.83), gumminess (6.69 N) and chewiness (23.30 mJ), while it was higher in resilience (0.25), cohesiveness (0.73) compared to control cake sample. **Conclusion:** Biscuit and cakes of lactose-free characterized with its nutritive values and sensory properties. Therefore, it could be recommended to produce such two products at industrial scale for its healthy and nutritive value for gluten-sensitive patients (celiac disease).

Key words: Lactose intolerance, lactose-free biscuits, brownness cakes

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

One of the nutritive components of milk is lactose, the principle sugar in milk and other dairy products. It is a disaccharide composed of glucose and galactose[1]. One of the problems related to lactose consumption is that some people amongst nations are not able to digest this sugar (nutrition related disease). They suffer from lactose intolerance[2] due to β-galactosidase enzyme deficiency in their digestive tract[3]. Nowadays lactose-free or lactose reduced products are in demand, where most humans, like other mammals, gradually lose the intestinal enzyme lactase after infancy and with it the ability to digest lactose. The symptoms of lactose intolerance differ from person to person depending on the amount of lactose consumed, lactase deficiency and the type of food, but commonly abdominal pain, diarrhea, nausea, flatulence and bloating are observed beginning 30 min to 2 h after dairy products consumption[4].

The frequency of lactose mal-digestion varies widely among populations, only 35% of world population can digest lactose beyond 7 or 8 age[5]. Europe has the lowest lactose intolerance incidence among populations. In Europe, 4-56% of people are lactose intolerant[6]. In North American adults lactose mal-digestion is found in approximately 79% of Native Americans, 75% of blacks, 51% of Hispanics and 21% of Caucasians. In Africa, Asia and Latin America prevalence rates range from 15-100% depending on the population studied[7]. Studies have shown that supplementation with probiotics, in addition to consuming yogurt that has been enhanced with certain types of bacteria, can alleviate symptoms of lactose intolerance by modifying the metabolic activity of microbiota in the colon[8].

Since fat provides the highest energy value of all major food constituents, fat substitution by other ingredients is a great challenge, especially in bakery products, as they can contain high levels of fat[9]. In bakery products, fat improve texture, mouth feel and flavor[10]. Also, fat provides several advantages to cakes, such as higher volume and softness in the final product[11]. Peanut is an important legume and food having peanut are highly accepted by consumers because of their divine flavor[12]. Peanut butter is a dispersion of peanut oil in peanut solids which results, when roasted peanuts are ground. Peanut butter is a good source of protein and fiber and low in fat. It is continually applied for the preparation of low calorie improved food products. Biscuits and cakes are popular foodstuff, consumed by a large number of populations today, due to their pleasant taste, prolonged shelf life and easy availability at fairly low cost[13]. Biscuits occupy primary position, both for production and consumption as compared to other bakery products[14].

It is likely that lactose free products will have different physical, sensory and chemical properties than others due to the complex interactions among different components. The present study is designed to produce and evaluate the composition and acceptability of lactose free cakes and biscuits prepared by replacing milk and dairy products with hydrogenated vegetable oils and peanut butter to alleviate symptoms of lactose intolerance in suffering individuals.

MATERIALS AND METHODS

Materials: Flour, sugar, butter, eggs, baking powder, oil, peanut and cocoa powder were purchased from local market "hyper" Egypt. Roasted peanuts were purchased from Institute of Agricultural Research Centre, Cairo, Egypt.

Methods: Peanut butter was prepared as follows: Peanut were heated at 165°C in oven for 5 min, cooled and red skin removed by rubbing the de shelled peanuts. Undesirable parts were removed, cleaned peanut kernels were subjected to grinding at medium speed in domestic mixer for 2 min. The ground product was spread on aluminum tray and left for 3 h followed by de-oiling, when oil separation was noticed on the surface of peanut butter. The peanut butter was packed in airtight glass container and stored in refrigerator (10°C) to prevent rancidity.

The biscuits were prepared as per standard recipe of AACC[15]. In case of peanut butter biscuits, dairy butter was substituted with peanut butter and natural honey was used instead of sugar.

Brownness cake was prepared as follows: Powdered sugar and butter were creamed in a dough mixer, then eggs and vanillin were added and mixed together at slow speed for 10 min. Cocoa powder and flour were added and mixed at high speed for 10 min. The mixed dough was put in a tray (20×30 cm), then the dough was baked in an oven at 180°C for 15 min. The cakes were allowed to cool for 1 h at room temperature, after which they were removed from the tray. The cooled cakes were packed in polyethylene bags at room temperature prior the physicochemical and sensory evaluation. In the lactose-free brownness cake, the same order of mixing as described for the control but dairy butter was substituted with sun flower oil (Table 1).

Analytical methods: Moisture, ash, fiber, protein and fat of cakes and biscuits were determined according to AOAC[16]. Total carbohydrates were calculated by difference.

Baking quality of cakes and biscuits: Volume (cm^3) and weight (g) of cake samples for each treatment were recorded. Specific volume (cm^3/g) was calculated as volume to weight according to the method described in AACC[15]. Weight, volume, specific volume, diameter, thickness (height) and spread ratio of biscuits were recorded, every parameter was measured in triplicate and the mean value was calculated.

Color determination: Color parameters (L*, a* and b*) of cakes and biscuit were determined using a spectro-colorimeter (Tristimulus Colour Machine) with the CIE lab color scale (Hunter, Lab Scan XE-Reston VA, USA) in the reflection mode. The instrument was standardized with white tile of Hunter Lab Cooler Standard (LX No. 16379): X = 72.26, Y = 81.94 and Z = 88.14 (L* = 92.46, a* = -0.86, b* = -0.16)

Texture analysis: Texture of the baked biscuit and cake samples was performed by texturometer, Brookfield model-CT3-10 kg, USA, equipped with a cylinder probe (TA.AACC36). Texture profile analysis (TPA) was conducted to determine hardness, adhesiveness, resilience, cohesiveness, springiness, gumminess and chewiness. The analyzer was set to perform two cycle measurements to give a two bite texture profile curve. Trigger load and test speed were 9.00 N and 2.5 mm sec, respectively.

Sensory evaluation: Sensory properties of biscuits and cakes were carried out with some modifications, according to Hussein *et al.*[17] by 15 trained panelists. The tested characteristics were color (20), texture (20), flavour (20), taste (20), appearance (20) and overall acceptability (100).

Freshness of cakes: Cakes freshness was tested after wrapping with polyethylene bags and stored at room temperature for 0, 1 and 3 days using Alkaline Water Retention Capacity test (AWRC) according to the method of AACC[15].

Statistical analysis: The obtained results were represented as a mean of triplicate samples ±Standard deviation (SD). Data were evaluated using the analysis of variance (ANOVA, one way) and differences between means of parameters were compared using the Duncan's test at the 5% significance level. Statistical analysis was performed as reported by Anderson and Gerbing[18].

Table 1: Formulation of brownness cakes and biscuits

	Brownness cake		Biscuit*	
Ingredients	Control	Lactose-free	Control	Lactose-free
Wheat flour (g)	200	200	260	260
Sucrose (g)	200	200	150	-
Butter (g)	200	-	230	-
Sun flower oil (g)	-	200	-	-
Coco powder (g)	200	200	-	-
Milk (mL)	20	-	20	-
Baking powder (g)	3	3	2	2
Vanillin (g)	0.5	0.5	0.5	0.5
Peanut butter (g)	-	-	-	230
Egg (No.)	3	3	-	-
Salt (g)	1	1	0.5	0.5
Honey (g)	-	-	-	150

*According to AACC[15]

RESULTS AND DISCUSSION

Color properties: Color is one of the most important sensory attribute that affects directly the consumer preference of bakery products. The color parameters of biscuits and cake samples were evaluated using a Hunter laboratory colorimeter (Table 2, 3). The L* scale ranges from 0 black to 100 white, the a* scale extends from negative value (green hue) to positive value (red hue) and the b scale ranges from negative blue to positive yellow. Table 2 showed that, lactose-free biscuits sample was slightly darker than control biscuits sample, where lightness (L*) and yellowness (b*) of control sample reached to 60.69 and 35.31, while lactose-free biscuit decreased slightly to 54.35 and 33.06, respectively.

Table 2: Effect of preparing lactose-free biscuit on its color parameters

Biscuit samples	L*	a*	b*
Control	60.69±2.13^a	10.47±0.71^b	35.31±1.95^a
Lactose-free	54.35±1.93^b	12.61±0.93^a	33.06±1.36^a
LSD at 5%	3.721	1.630	2.557

Values represented as a mean of triplicate samples ±SD, Values in the same column with different letters are significantly different ($p \leq 0.05$)

Table 3: Effect of preparing lactose-free brownness cake on its color parameters

Color parameters	Brownness cake (Control)	Lactose free brownness cake	LSD (5%)
Crust			
L*	28.51±1.13^a	23.84±1.03^b	2.170
a*	8.51±0.31^b	9.66±0.61^a	0.721
b*	10.26±0.35^a	10.62±0.55^a	0.541
Crumb			
L*	27.26±1.00^a	25.76±1.02^b	1.215
a*	9.00±0.28^b	10.37±0.25^a	0.698
b*	11.42±0.65^b	13.76±0.62^a	1.257

Values represented as a mean of triplicate samples ±SD, Values in the same row with different letters are significantly different ($p \leq 0.05$)

Furthermore, redness (a*) of lactose-free biscuit increased to 12.61 while it was 10.47 in control sample. This result could be attributed to addition of honey and peanut butter in lactose-free biscuits.

The color parameters of brownness cake (control sample) was compared with lactose-free brownness cakes shown in Table 3. The obtained results proved that lightness (L*) of crust and crumb increased slightly in control sample to 28.51 and 27.26, while it decreased slightly in crust and crumb of lactose-free cake to 23.84 and 25.76, respectively. While, a* and b* values of crust and crumb in control cake samples were decreased slightly compared to lactose-free brownness cake. This result could be attributed to the presence of sunflower oil instead of butter in lactose free brownness cake.

The results are in line with the results of a previous study, Siddiqui[19] who observed the similar trends. The reason of darker color of the biscuits might be due to higher level of protein present in the peanut butter. As protein reacts with carbohydrates during baking, Maillard reaction takes place which imparts darker color to biscuits.

Sensory properties: The effects of replacing honey and peanut butter in biscuits instead of lactose and sun flower oil to produce lactose-free biscuits and brownness cake were evaluated sensorial. Table 4 proved that honey and peanut butter in lactose-free biscuit affected slightly on taste and color, where taste of control and lactose-free biscuit were 17.45 and 18.78 and their color were 19.20 and 18.00, respectively. Furthermore, odor, texture, appearance and overall acceptability not affected significantly in lactose-free biscuit compared to control sample.

On the other hand, sensory properties of lactose free brownness cakes were evaluated. Table 4 showed that, lactose free brownness cakes were rated slightly higher in their odor (19.23) than the control brownness cakes (17.80). Furthermore, lactose-free brownness cakes not affected significantly in color, taste, texture, appearance and overall acceptability if compared with control brownness cake sample. No significant differences at $p<0.05$ were noted with lactose free brownness cake sand the control in taste, texture, appearance and overall acceptability.

Baking quality: Table 5 showed that baking quality of lactose free biscuits were affected by honey and peanut butter addition. Biscuit volume and weight of lactose-free samples increased significantly as a result of their formula, while the specific volume and spread ratio decreased significantly. This effect may be due to high fiber content in peanut butter, where fibers characterized by their high water holding capacity. This result agreed with El Shebini *et al.*[20] who stated that the addition of doum fruit flour to wheat flour led to increase the volume of biscuit due to increase in fiber content. Also, lactose-free biscuit characterized by its higher thickness and its diameter not affected compared to control biscuit sample.

The effect of preparing lactose free cake on baking quality was evaluated and presented in Table 5. The obtained results showed that all backing parameters

Table 4: Effect of preparing lactose free biscuit and brownness cakes on its sensory properties

	Biscuit			Brownness cakes		
Organoleptic characteristics	Control	Lactose-free	LSD (5%)	Control	Lactose-free	LSD (5%)
Color (20)	19.20±0.64^a	18.00±0.34^b	1.120	18.20±0.44^a	18.50±0.35^a	1.025
Taste (20)	17.45±0.23^b	18.78±0.50^a	1.222	18.18±0.60^a	18.45±0.63^a	1.023
Odor (20)	17.83±0.76^a	18.50±0.81^a	1.181	17.80±0.81^b	19.23±0.76^a	1.202
Texture (20)	19.00±0.41^a	18.80±0.45^a	1.103	19.05±0.42^a	19.50±0.55^a	1.513
Appearance (20)	18.70±0.67^a	18.5 0±0.89^a	1.329	19.00±0.67^a	19.30±0.89^a	1.753
Overall acceptability (100)	92.18±3.10^a	92.58±3.08^a	3.754	92.50±3.70^a	95.50±3.77^a	4.721

Values represented as a mean of triplicate samples ±SD, Values in the same row with different letters are significantly different ($p \leq 0.05$)

Table 5: Effect of preparing lactose-free biscuit and brownness cakes on its baking properties

	Biscuit			Brownness cakes		
Baking properties	Control	Lactose-free	LSD (5%)	Control	Lactose-free	LSD (5%)
Weight (g)	10.03±0.42^a	11.30±0.41^b	0.651	290±6.441	297±5.395	9.665
Volume (cm^3)	18.00±0.53^a	19.00±0.57^b	0.962	488±9.187	478±10.101	13.245
Specific volume (v\w)	1.79±0.05^a	1.68±0.05^b	0.095	1.68±0.08	1.61±0.06	0.091
Diameter (cm)	4.90±0.15^a	4.91±0.20^a	0.311			
Thickness (cm)	1.20±0.09^a	1.40±0.09^b	0.124			
Spread ratio	4.08±0.23^a	3.50±0.24^b	0.352			

Values represented as a mean of triplicate samples ±SD, Values in the same row with different letters are significantly different ($p \leq 0.05$)

Table 6: Effect of preparing lactose-free biscuit and brownness cakes on its chemical composition (dry weight basis)

	Biscuit			Brownness cakes		
Chemical composition (%)	Control	Lactose-free	LSD (5%)	Control	Lactose-free	LSD (5%)
Moisture	2.12±0.05[a]	3.38±0.08[b]	0.112	9.69±0.25[a]	7.29±0.19[b]	0.587
Ash	1.27±0.05[b]	2.05±0.04[a]	0.088	1.36±0.06[a]	1.34±0.05[a]	0.079
Protein	6.53±0.12[b]	13.49±0.15[a]	0.612	5.91±0.10[b]	7.55±0.10[a]	0.365
Fat	31.02±0.66[a]	22.75±0.72[b]	1.689	25.49±0.58[a]	24.38±0.56[a]	1.454
Fiber	0.32±0.01[b]	0.41±0.01[a]	0.056	1.53±0.02[a]	0.98±0.01[b]	0.089
CHO	60.86±2.10[a]	61.30±2.13[a]	3.956	65.71±1.17[a]	65.75±1.95[a]	3.187

Values represented as a mean of triplicate samples ±SD, Values in the same row with different letters are significantly different ($p \leq 0.05$)

(weight, volume and specific volume) not affected significantly compared to control cake sample.

Chemical composition: Data presented in Table 6 compared chemical composition of lactose free biscuit with control biscuit sample. Lactose free biscuit was characterized with its higher moisture (3.38%), protein (13.49%) and fiber contents (041%) and lower fat content (22.75%) compared to control biscuit. The obtained results were in agreement with Sudha *et al.*[21] and Alozie *et al.*[22], they noticed that gradual increase in moisture content of biscuits or cake with the increase in peanut butter percentage, which may be attributed to higher amount of fiber in peanut butter and fiber has higher water absorption. The results are in line with the results of Banureka and Mehendran[23], who reported that pulses and nuts have high amount of protein, when these protein rich sources are added to biscuits they add protein to it. Also, these findings are in accordance with the findings of Wekwete and Narder[24], who observed that peanut butter, had lower fat content than hydrogenated vegetable shortening. Hence, with increasing levels of peanut butter as a substitute for hydrogenated vegetable shortening the fat content of biscuit decreased, which is good for health.

Also, effect of preparing lactose-free cake on its chemical composition was evaluated as shown in Table 6. The obtain results indicated that lactose free brownness cake was characterized with its higher protein and lower moisture and fiber contents compared to control brownness cake.

Texture properties: Texture profile analysis is concerned with measurement of the mechanical properties of a product. Table 7 and 8 showed the effect of preparing lactose free biscuit or brownness cake on their texture parameters during two compression cycles. Fracturability of biscuit control sample reached to 83.91 N, while lactose-free biscuit decreased to 23.08 N. This result could be due to lactose-free biscuit containing honey and peanut butter related to higher moisture content. Hardness and fracturability of biscuit may be correlated to expansion and cell structure of the product,

Table 7: Effect of preparing lactose-free biscuit on its texture profile

	Biscuit	
Texture profile parameter	Control	Lactose-free
Cycle 1		
Hardness (N)	83.91	31.69
Adhesiveness force (N)	0.04	0.03
Adhesiveness (mJ)	0.20	0.00
Fracturability (N)	83.91	23.08
First fracture work done (mJ)	176.00	10.30
Cycle 2		
Hardness (N)	4.44	1.43
Cohesiveness	0.02	0.02
Chewiness (mJ)	3.70	1.10

Table 8: Effect of preparing lactose-free brown cake on its texture profile

	Brownness cake	
Texture profile parameter	Control	Lactose-free
Cycle 1		
Hardness (N)	69.75	9.10
Adhesiveness force (N)	0.77	0.07
Adhesiveness (mJ)	0.90	0.80
Resilience	0.03	0.25
Cycle 2		
Hardness (N)	46.30	9.12
Cohesiveness	0.18	0.73
Springiness index	4.68	0.83
Gumminess (N)	12.77	6.69
Corrected gumminess (N)	11.64	5.95
Chewiness (mJ)	59.80	23.30
Corrected chewiness (mJ)	54.50	20.80

independent of the feed moisture content. These results are in agreement with authors[25-27]. Adhesiveness is defined from sensory view as the work necessary to pull food away from a surface (e.g. tongue, teeth,... etc.), while adhesiveness force defined as the maximum force required to separate teeth after biting sample. Results proved that adhesiveness and adhesiveness force of lactose-free biscuits decreased to 0.00 mJ and 0.03 N compared to control biscuit sample (0.20 mJ and 0.04 N). On the other hand, hardness (i.e., second bite) of the peak force cycle two was decreased to 1.43 N for lactose-free biscuit, while it was 4.44 N in control biscuit sample. Cohesiveness is a measurement of how well the structure of a product withstand compression. Results

showed that cohesiveness of lactose-free biscuit not affected compared to control biscuit. Chewiness is sensory defined as the energy required to chew a solid food to the point required for swallowing it. Lactose free biscuit characterized with its lower chewiness (1.10 mJ) compared to biscuit of control sample (3.70 mJ).

Effect of preparing lactose-free brownness cake on its texture profile was evaluated during two compression cycles and presented in Table 8. Lactose free Brownness cake characterized with its lower hardness (9.10 N) and adhesiveness force (0.07 N) during the first compression cycle compared to control sample which reached to 69.75 N and 0.77 N, respectively. Resilience is defined from sensory view as measurement of how a sample recovers from deformation in relation to speed and forces derived. Results showed that lactose free brownness cake characterized with its higher resilience (0.25) compared to control cake sample (0.03). On the other hand, hardness of the second cycle decreased in control cake sample to 46.30 N, while Lactose free brownness cake not affected (9.12 N). Therefore, cohesiveness of lactose free brownness cake was higher (0.73) than control sample (0.18). Springiness index defined as ratio of the height sample springs back after the deformation of the first and second chews. Results indicated that springiness index of lactose free brownness cake characterized with its lower springiness index (0.83) compared to control cake sample (4.68). Also, lactose free brownness cake characterized with its lower gumminess (6.69 N) and chewiness (23.30 mJ) compared to control cake sample (12.77 N and 59.80 mJ). Variation in TPA profile could be due to replacing sun flower oil instead of butter in lactose free brownness cake. Where, Sudha *et al.*[21] reported that fat coats the surface of the flour particles inhibiting the development of the gluten proteins. The free fat therefore disrupts the gluten network resulting in softer doughs[28].

CONCLUSION

Lactose-free biscuit contained higher percentage of protein and fiber and lower fat compared to control biscuit sample. Such formula affected slightly on sensory and texture profile properties, where it have lower fracturability, adhesiveness, adhesiveness force and chewiness compared to biscuit of control sample. Also, lactose-free brownness cake contained higher protein, lower moisture and fiber compared to control sample. Furthermore, it was not affected significantly in sensory. Also, lactose-free brownness cake characterized with its lower hardness, adhesiveness force, springiness index, gumminess and chewiness, while it was higher in resilience (0.25), cohesiveness (0.73) compared to control cake sample. It could be recommended to produce such two products at industrial scale for its healthy and nutritive value.

SIGNIFICANCE STATEMENT

In this study we provide two new formulations of biscuits and brownness cakes devoid of lactose. This is remarkably important for individuals suffering from lactose intolerance to ease their life by alleviating the symptoms of that disease. This also opens the way for innovative research in the same field.

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